EFFECT OF ADDING SPIRAL REINFORCING TO VERTICALLY REINFORCED CONCRETE COLUMNS

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VERTICALLY REINFORCED CONCRETE COLUMNS.

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A THESIS

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Dean of Cultural Studies.

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INTRODUCTION

The object of this thesis is to determine the effect of adding spiral reinforcing to vertically reinforced concrete columns. Although much similar work has been done in the past, a new feature of the work was that the deformations of the spiral steel were accurately measured. The deformations of the spiral steel being known, the corresponding stresses in the steel were taken from the stress-strain sheets. This latter feature of the work, so far as is known, has not been attempted in the past.

The authors also felt that by a careful study of the work and of the materials employed, a great deal of practical information could be obtained.

Two columns, ten feet in length by ten and one-half inches in diameter were experimented upon. Column No. 1 contained only longitudinal reinforcing, whereas Column No.2 contained both longitudinal and spiral reinforcing.

MATERIALS

<u>Cement</u> The cement used was Chicago A-A Portland. The cement was tested in compliance with standard methods so as to determine its fitness for the work, the results of which are shown below.

Fineness Test

200 gms. of dried sample was placed in the "Per Se" Testing Sieve Agitator which was operated for ten minutes.

Table 1

Cement Sieve Analysis

Sieve No.	Grams Retained	Per Cent Retained	Per Cent Passing	Weight per Cu.Ft. lbs.
10	0	0	100.00	
20	0	0	100.00	
30	0	0	100.00	
40	.10	.05	99.95	
50	2.15	1.10	98.85	
60	.96	.49	98.36	
80	12.57	6.42	91.94	
100	13.40	6.85	85.09	
200	61.30	31.35	53.74	
Passing all	106.35	54.30	100.56	95
Total	195.83	100.92		

Four briquettes of neat cement of a consistency of twenty-five per cent (which had been previously determined) and also four briquettes of a 1:3 mixture were made, the strengths of which are shown in Table 2.

Table 2
Tensile Strength of Cement

Average Strength of Two Briquettes, lbs/in^2			
Neat		1:3 Mortar	
Age in Days		Age in Days	
7	28	7	28
443	740	330	437

Sand The sand was standard Ottowa testing sand. The results of the sieve analysis, which was performed similar to that of the cement, are shown in Table 3.

The voids in the sand were determined by means of the "graduate" method.

Volume of water = 60 c.c.

Volume of saturated mixture = 195 c.c.

$$\% \text{ voids} = \frac{60}{195} \times 100\% = 30.8\%$$

Second Trial -

$$\% \text{ voids} = \frac{60}{200} \times 100\% = 30\%$$

Therefore a value of 30% will be used.

Table 3
Sand Sieve Analysis
500 Gram Sample

Sieve No.	Grams Retained	Per Cent Retained	Per Cent Passing	Weight per Cu.Ft. lbs.
10	165.30	33.50	66.50	
20	95.10	19.25	47.25	
30	84.10	17.00	30.25	
40	60.60	12.25	18.00	
50	61.10	12.38	5.62	
60	12.45	2.52	3.10	
80	7.65	1.55	1.55	
100	3.00	.61	.94	
200	2.00	.40	.54	
Passing all	2.60	.53	.01	101.6
Total	493.90	99.99		

<u>Stone</u> The stone used was crushed limestone, graded and ranging in size from 1/4" to 3/4". The voids in the stone were determined by means of the "pail method."

Weight of pail empty	=	19.72
Weight of pail plus water	=	56.02
Weight of water	=	36.30

$$\text{Volume of pail} = \frac{36.30}{62.5} = .5808 \text{ cu. ft.}$$

Wt. of pail + crushed stone		= 69.21
" " " + " "	+ water	= 86.62
" " water		= 17.14

Hence % voids is $\frac{17.41}{36.30}$ x 100% = 47.96% = 48%

<u>Longitudinal Steel</u> The longitudinal reinforcing consisted of 1/2" round bars of medium structural steel. Since eight bars were to be used in the column, this afforded a reinforcement of 2.1% of the area within the hooping.

Three samples of this steel which had been machined off to lengths of about two and one-half inches were tested for compression in a 60,000 lb. Olsen testing machine. The tables and curves resulting are shown later.

<u>Spiral Steel</u> The spiral reinforcing consisted of 3/16" steel twisted into spirals 9-3/4 inches in diameter and spaced to a pitch of one inch by means of two vertical spacers. This afforded a reinforcement of 2.76% of the area within the hooping. The spiral was

furnished complete by the F. P. Smith Wire & Iron Works.

A sample was subjected to a tensile test, the results of which are shown later.

Concrete The proportions to be used in mixing the concrete were determined from the results of the sieve analysis. The method of computation is shown below.

Data

Voids in stone = 48%

Voids in sand = 30%

Use 40% excess of mortar over the voids in the sand.

Since cement pasto has .8 volume of dry cement, a shrinkage factor of .8 will be used.

Assume 100 parts of crushed stone.

No. parts of mortar = .48 x 100 x 1.4 = 67.2

Mortar = sand + cement

$$67.2 = S(1 - .3) + \frac{S(.30) \times 1.2}{.8}$$

Solving, S = 60.5 parts of sand.

$$\frac{60.5 \times .3 \times 1.2}{.8} = 27.2 \text{ parts cement}$$

Hence the following proportions by volume are required:

Cement		Sand		Cr. Stone
27.2	:	60.5	:	100
1	:	2.22	:	3.68

Since the measuring was done by weight rather than volume, these proportions were reduced to units of weight as shown in Table 4.

Table 4

	Cement	Sand	Stone
Wt. per Cu. Foot	95	101.6	93.6
Parts by Volume	1	2.22	3.68
Den. rel. to cement	$\frac{95}{95} = 1$	$\frac{101.6}{95} = 1.07$	$\frac{93.6}{95} = .985$
Parts by Weight	1	1.07 x 2.22 = 2.37	.985 x 3.68 = 3.62

It was thought advisable to go to this detail in order that a voidless mixture might be obtained without unnecessary waste. Test cylinders 7" x 16" were also made when the columns were poured, the strength of the plain concrete thus being obtainable. The tables and curves are shown later.

MAKING AND CURING

Forms The forms for the columns were built of one and one-half inch pine and to simplify the construction they were made octagonal in shape. The form consisted of eight lateral strips of timber, the edges of which had been beleled to a twenty-two and one-half degree angle so as to secure a snug fit. The bottom consisted of a two inch octagonal piece which was inserted in the bottom and made secure by two cleats of 2" x 4" stuff. On the upper face of this piece had been tacked eight small chips of wood which had three-quarter inch circular notches in them; the idea being that these would aid the placing of the vertical reinforcing and furthermore it was desired that there be one-quarter of an inch clearance between the end of the reinforcing and the bottom of the column.

The bracing consisted of two by fours bolted at the ends. One such set came into

contact with four sides of the form. Ten sets in all were used so as to give sufficient rigidity. The bracing, after being drawn over the form, was made secure by hammering shingles between the bracing and the form. Thus the form was absolutely rigid throughout.

The inside of the form was dampened with an oily rag so as to secure an easy removal after the columns had set. (See Plate No. 1)

The forms for the test cylinders, which were seven inches in diameter and sixteen inches in height, consisted of rectangular strips of galvanized iron rolled into a cylindrical shape. These were fastened to a board base ~~being~~ by flaring out the lower edges and inserting them between the two boards which in turn were bolted together. Two such forms were used since two test cylinders for each column were desired.

Pouring The ingredients were weighed on a platform scale and mixed on a board platform. The sand was first spread out and the dry cement spread over it; the two then being thoroughly mixed. Enough water was then added to produce a wet paste. The stone was then added and the three thoroughly mixed by "turning over" three or four times. The mixture was made of a consistency such that a puddle would form without much difficulty when tamped in the forms.

The columns were cast on end and consequently a seven foot scaffold was built, upon which the pouring and tamping could be done. The mixture was transferred from the mixing platform to the scaffold platform in water buckets, one man doing the carrying and the other doing the pouring and tamping. In tamping, a long thin pole was used.

Each column was mixed in three batches in order that the mixture could be used

before an initial set could have taken place and also because it made the mixing somewhat easier. The mixture was made flush with the top of the forms, being leveled off by means of a mason's trowel. Two days later, after evaporation and shrinkage had taken place, the top of the column was again made flush with a mixture of neat cement.

Previous to the pouring the longitudinal roads had been spaced by some 1/8" x 1/4" steel strips bent into rings. Ten of these rings were used in all in order to hold the rods securely in position until the pouring was well advanced. In the case of Column No. 2 the spiral steel was wired directly around the longitudinal steel, little difficulty being experienced.

<u>Curing</u> The column was allowed to remain in the form seven days, after which it was laid in a horizontal position and the forms removed. From this time on, water was applied

once a day to assist the column in its final set. The temperature of the laboratory varied from fifty to eighty degrees. The raising and lowering of the columns was accomplished by means of a fifteen hundred pound crane which was suspended from a roof truss.

METHOD OF TESTING

Testing Machine The testing machine in which the columns were tested was a 400,000 lb. Olsen motor-driven machine which had just recently been installed in the new refrigeration laboratory. The machine used in testing the small cylinders was a 200,000 lb. Rhiele testing machine, situated in the Mechanical laboratory. The propelling screws of the larger machine were protected by strips of cheese cloth which were hung along the sides.

Extensometer The extensometer used on the small cylinders consisted of two brass rings and two vertical brass rods extending between them. Each ring was fastened to the column by means of four set screws. A battery, a series of wire, and a bell were so connected with the arrangement that when a contact was made, the bell sounded. By means of this delicate arrangement and a micrometer scale,

readings were taken to ten-thousandths of an inch. The reading on each arm was taken and the average of the two taken as the actual deformation.

The extensometer for the columns had two steel bars 1" x 1/4" x 15" connected across by means of two 1/4" threaded rods which had a movement of about two inches. Four set screws passed through the steel bars for the points of contact. The distance between the two sections was 3' 8" and this was spanned by inserting extensions in the bars used on the original extensometer which was used for the small cylinders. Thus the extensometer could be altered so as to be used on either the columns or the test cylinders.

Before testing, layers of padding paper were inserted at both ends of the columns so as to insure a good distribution of the load. The columns were necessarily made plumb before testing. The load was applied in increments

of five thousand pounds, readings being taken at each point. (Note: Small 1/2" dia. rods projecting three inches on either side had been previously inserted in the moulding to assist in the handling of the columns later on. Two rods were inserted in each column, one at each third point.

<u>Spiral Extensometer</u> The spiral deflections were measured by means of a ribbon tape which was wound about the columns in direct contact with the steel. The concrete had been previously chipped to the level of the spirals and the steel polished and rubbed with an oily rag so as to reduce the friction between the spirals and the tape to a minimum. Six complete revolutions of spiral were thus exposed, the tape being soldered at the upper end. At the lower end of the tape was riveted one inch of extremely fine steel which had been graduated to one-hundredths of an inch. This in turn was attached to a

metal spring which held the tape taut. A zero reading was taken using a small scratch on the spiral as a reference point. Since the graduations were so small as to make the readings with the naked eye impossible, a transit of high magnifying power was employed. The transit was stationed about ten feet from the column. By means of this arrangement, movements of twenty-five ten-thousandths of an inch were detected. This, therefore, gives a very accurate means of detecting the deformations, the degree of accuracy being 1/4%.

Since the partial removal of the outer shell does not materially affect the strength of the column, the effective diameter used in the computations was taken as the diameter included by the spirals only.

DISCUSSION

The discussion of the results will include a comparison of (a) The plain concrete cylinder and the longitudinally reinforced column, (b) The longitudinally reinforced column and the combined longitudinally and spirally reinforced column.

(a) The vertical reinforcing increased the ultimate strength of the plain concrete from sixteen hundred pounds per square inch, as shown in the cylinder test, to twenty-two hundred and fifty pounds per square inch as shown in the test of column No. 1. It also increased the stiffness and prolonged the yield point. In fact, no definite yield point can be observed from the curve. The point of failure and the yield point thus seem to be one and the same.

(b) Column No. 2 acted practically the same as Column No. 1 up to the point at which Column No. 1 failed. The spiral steel seemed

to have little if any appreciable effect up to this point. This point, however, constituted the yield point of Column No. 2. The spiral steel now came into action as was shown by the deflections. The spiral deflections seemed to increase in proportion to the increase of load. The deformations being known, the stress per square inch was taken from the stress-strain curve. However, the failure did not occur between the points of measurement, but within two feet of the base. The spirals at that point snapped and allowed the vertical steel to buckle outward. The results show that the spirals under measurement had not yet reached the elastic limit.

The longitudinal bars sustained a certain part of the load and were also available for spanning over places of local weakness in the concrete. In the case of the spiral reinforcing, the hooping was of service in tending to keep in place the material after local disintegration was well advanced.

CONCLUSION

A summary of the results and discussion is expressed in the following:

1. The column reinforced with vertical steel only was brittle and failed suddenly when the yield point of the steel was reached, but was considerably stronger than the plain cylinder made from the same grade of concrete.

2. The hooped column sustained without crushing a considerably heavier load and failed only a long time after cracks in the surface and exaggerated deformation had given warning of the danger.

3. The longitudinal reinforcement controlled the yield point and increased the stiffness, whereas the spiral reinforcement controlled the ultimate strength and increased the toughness.

4. The hooping did not come into action to any great extent before a load equivalent

to the ultimate strength of the unhooped column or a little below was reached. The longitudinal deformation and the lateral deformation were not modified by the hooping to any great extent before this load was reached.

5. However, after this load was reached, the longitudinal deformations became very great and the lateral deformations, which were measured by the spiral expansion, seemed to vary proportionally to the load.

6. The protecting shell did not carry load, especially after the steel yielded, since no effect was noticed on the stress-strain curve even long after the shell had cracked and spalled off.

LOG SHEET FOR VERTICAL REINFORCING SAMPLE 1

Original Average Diameter = .50145 in.
Original Average Area = .19745 sq. in.
Length Under Measurement = 2 in.

LOAD		COMPRESSOMETER			COMPRESSION		MODULUS OF
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per In.	ELAST. E
0	0	2.0555	2.0570	2.0562	0	0	---
600	3400	.0551	.0570	.0561	.0001	.000049	60,800,000
2600	13200	.0545	.0560	.0552	.0010	.000490	26,900,000
3750	19000	.0542	.0552	.0547	.0015	.000732	26,000,000
4850	24600	.0540	.0549	.0545	.0017	.000830	29,600,000
5700	29000	.0539	.0543	.0541	.0021	.001025	28,300,000
6430	32600	.0535	.0541	.0538	.0024	.001170	27,800,000
7050	35800	.0537	.0540	.0535	.0027	.001320	27,100,000
7600	38600	.0530	.0539	.0535	.0027	.001320	29,200,000
7950	40300	.0529	.0539	.0534	.0028	.001370	29,400,000
8320	42200	.0499	.0522	.0510	.0052	.002540	16,600,000
8500	43100	.0488	.0509	.0498	.0064	.003120	13,800,000
8400	42500	.0475					
8500	43100	.0460	.0460	.0460	.0102	.004930	8,730,000
8450	42750	.0447	.0432	.0454	.0108	.005270	8,120,000
8400	42500	.0428	.0398	.0443	.0119	.005810	7,310,000
8430	42700	.0390	.0351	.0371	.0191	.009320	4,575,000
8450	42750	.0311	.0289	.0300	.0262	.012800	3,340,000
8550	43300	.0202	.0160	.0181	.0381	.018600	2,320,000
8650	43800	.0080					

Compression Removed — Divider Readings

8650	43900	1.9520	.048	.0240	1,830,000
8950	45500	1.951	.049	.0245	1,860,000
9300	47250	1.925	.075	.0375	1,260,000
9700	49250				

Failure by Bending

Ultimate Strength = 49,250 lbs. per sq. inch

LOG SHEET FOR VERTICAL REINFORCING SAMPLE 2

Original Average Diameter = .4986 in.
Original Average Area = .2235 sq. in.
Length Under Measurement = 2 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L	R	Mean	Actual	Per Inch	E
50		2.0615	2.0671	2.0643			
600	2685	.0616	.0669	.0642	.0001	.000048	56,000,000
1050	4700	.0615	.0668	.0641	.0002	.000096	49,000,000
1900	8500	.0614	.0660	.0637	.0006	.000288	29,500,000
3300	14800	.0610	.0650	.0630	.0013	.000630	23,500,000
4450	19900	.0608	.0647	.0627	.0016	.000775	25,700,000
5450	24400	.0604	.0640	.0622	.0021	.001020	23,900,000
6300	28200	.0601	.0640	.0620	.0023	.001115	25,300,000
7250	32400	.0600	.0639	.0620	.0023	.001115	29,100,000
7650	34200	.0592	.0639	.0616	.0027	.001310	26,100,000
7750	34700	.0590	.0639	.0614	.0029	.001405	24,700,000
8100	36200	.0588	.0634	.0611	.0032	.001550	23,400,000
8350	37400	.0584	.0625	.0604	.0039	.001890	19,800,000
8530	38200	.0576	.0600	.0588	.0055	.002665	14,300,000
8650	38700	.0560	.0558	.0559	.0084	.004070	9,510,000
8350	37400	.0560	.0558	.0559	.0084	.004070	9,200,000
8600	38400	.0542	.0525	.0533	.0110	.005330	7,200,000
8350	37400	.0541	.0525	.0533	.0110	.005330	7,025,000
8530	38200	.0511	.0482	.0496	.0147	.007120	5,370,000
8350	37400	.0511	.0482	.0496	.0147	.007120	5,260,000
8580	38400	.0470	.0435	.0452	.0191	.009250	4,160,000
8350	37400	.0469	.0432	.0450	.0193	.009340	4,000,000
8700	38900	.0390	.0349	.0369	.0274	.013300	2,930,000
8350	37400	.0388	.0347	.0367	.0276	.013380	2,800,000
8650	38700	.0300	.0252	.0276	.0367	.017780	2,180,000
8350	37400	.0297	.0251	.0274	.0369	.017850	2,100,000
8750	39200	.0184	.0144	.0164	.0479	.023200	1,690,000
	Divider Readings between original 2" Points						
8750	39600	1.97			.03	.015	2,640,000
8980	39900	1.95			.05	.025	1,600,000
11400	51000						

Ultimate Strength = 51,000 lbs. per sq. inch

LOG SHEET FOR VERTICAL REINFORCING SAMPLE 3

Original Average Diameter = .4993 in.
Original Average Area = .1958 sq. in.
Length Under Measurement = 2 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L	R	Mean	Actual	Per Inch	E
180		2.0638	2.0580	2.0690	.0000		
890	4550	.0638	.0576	.0607	.0002	.000097	46,900,000
2300	11750	.0637	.0566	.0601	.0008	.000388	30,300,000
3500	17880	.0635	.0560	.0597	.0012	.000582	30,700,000
4600	23450	.0630	.0558	.0594	.0015	.000727	32,300,000
5400	27600	.0628	.0555	.0591	.0018	.000872	31,700,000
6170	31500	.0624	.0540	.0582	.0027	.001310	24,000,000
7050	36000	.0619	.0505	.0562	.0047	.002280	15,800,000
7350	37600	.0618	.0490	.0554	.0055	.002670	14,100,000
7800	39800	.0611	.0465	.0538	.0071	.003440	11,580,000
8150	41650	.0600	.0419	.0509	.0100	.004850	8,600,000
8300	42400	.0550	.0355	.0452	.0157	.007610	5,580,000
8200	41850	.0528	.0323	.0425	.0184	.008920	4,700,000
8400	42850	.0450	.0280	.0365	.0244	.011340	3,620,000
8300	42350	.0465	.0245	.0355	.0254	.012320	3,440,000
8380	42750	.0410	.0240	.0325	.0284	.013800	3,095,000
8400	42850	.0350	.0187	.0268	.0341	.016540	2,590,000
8420	43000	.0285	.0127	.0206	.0403	.019550	2,200,000
8700	44400	.0224	.0067	.0145	.0464	.022500	1,975,000
8900	45500	.0190	.0027	.0108	.0501	.024300	1,870,000

Compressometer Removed

12500 63800 Maximum

Ultimate Strength = 45,500 lbs. per sq. inch

LOG SHEET FOR SPIRAL REINFORCING

Original Average Diameter = .1761 in.
Original Average Area = .024355 sq. in.
Length Under Measurement = 4 in.

LOAD Actual	LOAD Per Sq. Inch	EXTENSOMETER READINGS L	EXTENSOMETER READINGS R	EXTENSOMETER READINGS Mean	EXTENSION Actual	EXTENSION Per Inch	MODULUS OF ELASTICITY E
150	6170	.0043	.0063	.0053	.0008	.00010	61,700,000
400	20520	.0067	.0097	.0082	.0037	.00046	44,600,000
600	24640	.0090	.0124	.0107	.0062	.00077	32,000,000
800	32880	.0108	.0150	.0129	.0084	.00105	31,300,000
1000	41080	.0129	.0177	.0153	.0108	.00135	30,400,000
1200	49280	.0152	.0200	.0176	.0131	.00164	30,000,000
1400	57600	.0182	.0224	.0203	.0158	.00198	29,100,000
1500	61600	.0194	.0235	.0214	.0169	.00211	29,200,000
1600	65800	.0212	.0248	.0230	.0185	.00231	28,500,000
1700	69800	.0230	.0277	.0253	.0208	.00260	26,800,000
1800	74000	.0247	.0280	.0263	.0218	.00272	27,200,000
1900	78000	.0277	.0314	.0295	.0250	.00312	25,000,000
2000	82200	.0294	.0333	.0313	.0268	.00335	24,500,000
2100	86400	.0328	.0372	.0350	.0305	.00381	22,700,000
2200	90400	.0369	.0422	.0395	.0350	.00438	20,600,000
2300	94400	.0430	.0480	.0455	.0410	.00512	18,400,000
2400	98800	.0514	.0560	.0537	.0492	.00615	16,050,000
2420	99600	.0545	.0660	.0602	.0557	.00696	14,300,000
2500	102600						

Ultimate Strength = 102,600 lbs. per sq. inch

LOG SHEET FOR CYLINDER 1 OF COLUMN No. 1

Original Average Diameter = 7.03 in.
Original Average Area = 38.8144 sq. in.
Length Under Measurement = 12 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
0		.0032	.0010	.0021	0	0	
4400	113.5	.0032	.0019	.00255	.00045	.00004	2,830,000
9000	232	.0030	.0030	.0030	.0009	.00008	2,900,000
14300	369	.0023	.0045	.0034	.0013	.00011	3,360,000
17700	456	.0021	.0056	.00385	.00175	.00015	3,040,000
23000	592	.0016	.0076	.0046	.0025	.00021	2,820,000
25400	655	.0013	.0092	.00525	.00315	.00026	2,520,000
28000	721	.0010	.0105	.00575	.00365	.00030	2,400,000
30450	785	.0004	.0120	.0062	.0041	.00034	2,310,000
33300	864	.0000	.0140	.0070	.0049	.00041	2,110,000
35200	908	-.0006	.0158	.0076	.0055	.00046	1,970,000
36500	915	-.0010	.0169	.00795	.00585	.00049	1,870,000
39000	1005	-.0016	.0196	.0090	.0069	.00058	1,740,000
41400	1066	-.0021	.0217	.0098	.0077	.00064	1,670,000
44000	1133	-.0031	.0248	.01085	.00875	.0073	1,550,000
46000	1185	-.0042	.0285	.01215	.01005	.00084	1,410,000
48500	1250	-.0047	.0320	.01365	.01155	.00096	1,300,000
51400	1325	-.0060	.0360	.0150	.0139	.00116	1,140,000
54400	1405	-.0074	.0425	.01755	.01545	.00128	1,095,000
55300	1425	-.0088	.0498	.0205	.0184	.00153	932,000
57900	1490	-.0093	.0547	.0227	.0206	.00172	866,000
59500	1530	-.0099	.0607	.0254	.0233	.00194	789,000
61500	1586	-.0112	.0705	.02915	.02705	.00226	700,000
63000	1624	-.0110	.0847	.03685	.03475	.00290	561,000

Ultimate Strength = 1624 lbs. per sq. inch

LOG SHEET FOR CYLINDER 2 OF COLUMN No. 1

Original Average Diameter = 6.975 in.
Original Average Area = 38.2097 sq. in.
Length Under Measurement = 12 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
0		.0004	.0008	.0006	0		
5000	131	-.0006	.0011	.00025	.0000	0	
9780	256	-.0005	.0020	.00075	.00015	.00001	25,600,000
16000	419	-.0009	.0039	.00150	.0009	.00008	5,240,000
20600	539	-.0010	.0056	.0023	.0017	.00014	3,850,000
23000	602	-.0009	.0069	.0030	.0024	.00020	3,010,000
25500	668	+.0002	.0072	.0037	.0031	.00026	2,570,000
27640	724	-.0001	.0089	.0044	.0038	.00032	2,260,000
31400	822	-.0007	.0104	.00485	.00425	.00035	2,350,000
33700	883	-.0010	.0120	.0055	.0049	.00041	2,150,000
35800	938	-.0018	.0141	.00615	.00555	.00046	2,040,000
37600	985	-.0024	.0167	.00715	.00555	.00046	2,140,000
40000	1047	-.0030	.0192	.0080	.0074	.00062	1,690,000
43000	1125	-.0045	.0222	.00885	.00825	.00069	1,630,000
47000	1230	-.0050	.0259	.01045	.00985	.00082	1,500,000
48000	1257	-.0074	.0345	.01355	.01295	.00107	1,170,000
50800	1330	-.0091	.0417	.0163	.0157	.00131	1,015,000
54000	1414	-.0117	.0486	.01845	.01785	.00149	950,000
57000	1492	-.0138	.0622	.0242	.0236	.00197	757,000
59000	1543	-.0172	.0952	.0390	.0384	.00320	482,500

Ultimate Strength = 1,543 lbs. per sq. inch

LOG SHEET FOR CYLINDER 1 OF COLUMN No. 2

Original Average Diameter = 6.965 in.
Original Average Area = 38.1013 sq. in.
Length Under Measurement = 12 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
350	9.2	.0048	.0023	.0036	.00000	0	
3400	89.	.0050	.0020	.0035	.00000	0	
6000	158.	.0056	.0020	.0038	.0002	.00002	7,900,000
9000	236.	.0063	.0023	.0043	.0007	.00006	3,933,000
12000	289.	.0075	.0023	.0049	.0013	.00010	2,890,000
15000	394.	.0080	.0020	.0050	.0014	.00011	3,580,000
18000	473.	.0091	.0026	.0058	.0022	.00018	2,630,000
21000	552.	.0103	.0026	.0065	.0029	.00024	2,300,000
23000	603.	.0113	.0026	.0069	.0033	.00028	2,150,000
25000	657.	.0124	.0030	.0077	.0041	.00034	1,930,000
27500	722.	.0139	.0031	.0085	.0049	.00041	1,760,000
30000	788.	.0161	.0039	.0100	.0064	.00053	1,480,000
32500	853.	.0202	.0037	.0119	.0083	.00069	1,240,000
35000	920.	.0287	.0048	.0167	.0131	.00101	910,000
37500	985.	.0447	.0076	.0261	.0225	.00137	526,000

Shear Failure   Exceedingly Weak.

Ultimate Strength = 985 lbs. per sq. in.

LOG SHEET FOR CYLINDER 2 OF COLUMN No. 2

Original Average Diameter = 7.000 in.
Original Average Area = 38.4846 sq. in.
Length Under Measurement = 12 in.

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
0	0	.0098	.0012	.0055	0	0	
3000	78	.0101	.0016	.0058	.0003	.00002	3,900,000
6000	156	.0111	.0008	.0060	.0005	.00004	3,900,000
9000	234	.0117	.0007	.0062	.0007	.00006	3,900,000
12000	312	.0131	.0010	.0070	.0015	.00012	2,600,000
15000	390	.0137	.0005	.0071	.0016	.00013	3,000,000
18000	468	.0149	.0005	.0077	.0022	.00018	2,600,000
20000	520	.0158	.0003	.0080	.0025	.00021	2,480,000
22500	584	.0165	.0002	.0088	.0033	.00027	2,160,000
25000	650	.0175	.0000	.0088	.0033	.00027	2,400,000
27500	714	.0187	.0001	.0094	.0039	.00032	2,230,000
30000	780	.0203	.0000	.0101	.0045	.00037	2,100,000
32500	845	.0218	-.0008	.0107	.0052	.00043	1,960,000
35000	910	.0232	-.0002	.0115	.0060	.00050	1,820,000
37500	974	.0250	-.0003	.0123	.0068	.00057	1,710,000
40000	1040	.0272	-.0007	.0132	.0077	.00064	1,620,000
42500	1100	.0298	-.0007	.0145	.0090	.00075	1,470,000
45000	1170	.0318	-.0009	.0154	.0099	.00012	1,430,000
47500	1230	.0347	-.0012	.0167	.0112	.00093	1,320,000
50000	1300	.0378	-.0013	.0182	.0127	.00106	1,220,000
52500	1360	.0420	-.0012	.0204	.0149	.00124	1,090,000
56000	1450	.0502	-.0007	.0247	.0192	.00160	906,000
58000	1510	.0545	-.0007	.0269	.0214	.00178	848,000
60000	1560	.0626	.0000	.0313	.0258	.00215	726,000
62000	1610	.0746	+.0029	.0387	.0332	.00276	583,000

Shearing Failure

Ultimate Strength = 1610 lbs. per sq. inch

LOG SHEET FOR COLUMN NO. 1

Original Effective Average Diameter = 9.5 in.
Original Effective Average Area = 70.8807 sq. in.
Length Under Measurement = 44.5 in.
Percentage of Longitudinal Reinforcement = 2.1

LOAD Actual	LOAD Per Sq. Inch	COMPRESSOMETER READINGS L.	COMPRESSOMETER READINGS R.	COMPRESSOMETER READINGS Mean	COMPRESSION Actual	COMPRESSION Per Inch	MODULUS OF ELASTICITY E
5000	70.5	-.0001	.0071	.0035	.0005	.000011	6,420,000
10000	141	.0015	.0071	.0043	.0013	.000029	4,870,000
15000	218	.0025	.0065	.0045	.0015	.000033	6,620,000
20000	282	.0038	.0061	.0050	.0020	.000045	6,270,000
30000	423	.0059	.0057	.0058	.0028	.000063	6,710,000
40000	564	.0099	.0055	.0077	.0047	.000105	5,370,000
45000	635	.0112	.0051	.0082	.0052	.000117	5,425,000
50000	705	.0124	.0050	.0087	.0057	.000128	5,510,000
55000	776	.0144	.0049	.0097	.0067	.000151	5,140,000
60000	847	.0166	.0049	.0107	.0077	.000173	4,900,000
65000	918	.0179	.0048	.0114	.0084	.000189	4,860,000
70000	988	.0197	.0044	.0121	.0091	.000204	4,850,000
75000	1057	.0211	.0042	.0127	.0097	.000218	4,850,000
80000	1130	.0228	.0043	.0136	.0106	.000238	4,750,000
85000	1200	.0248	.0040	.0144	.0114	.000256	4,690,000
90000	1270	.0266	.0039	.0153	.0123	.000277	4,580,000
95000	1340	.0290	.0041	.0166	.0136	.000306	4,370,000
100000	1410	.0307	.0040	.0174	.0144	.000324	4,360,000
105000	1480	.0327	.0038	.0183	.0153	.000344	4,310,000
110000	1551	.0348	.0036	.0192	.0162	.000364	4,150,000
115000	1632	.0371	.0040	.0206	.0176	.000396	4,100,000
120000	1693	.0390	.0044	.0217	.0187	.000420	4,030,000
124000	1750	.0407	.0044	.0225	.0195	.000438	4,000,000
128000	1805	.0420	.0045	.0233	.0203	.000456	3,960,000
134000	1890	.0462	.0054	.0258	.0228	.000512	3,690,000
136000	1920	.0470	.0055	.0263	.0233	.000523	3,670,000
140000	1975	.0485	.0061	.0273	.0243	.000546	3,620,000
144000	2030	.0492	.0065	.0279	.0249	.000560	3,630,000
148000	2090	.0504	.0077	.0291	.0261	.000586	3,570,000
152000	2145	.0650	.0113	.0381	.0351	.000709	3,030,000

Ultimate Strength = 2145 lbs. per sq. inch

LOG SHEET FOR COLUMN NO. 2

Original Effective Average Diameter = 9.73 in.
Original Effective Average Area = 74.355 sq. in.
Length under Measurement = 44.5 in.
Percentage Longitudinal Reinforcement = 2.1
Percentage Spiral Reinforcement = 2.76

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
2100	28.3	.0192	.0027	.0109	.0002	.000004	7,070,000
10000	134.7	.0202	.0033	.0117	.0010	.000022	6,120,000
20000	269	.0224	.0039	.0131	.0024	.000054	4,980,000
32000	431	.0249	.0045	.0147	.0040	.000090	4,780,000
40000	538	.0263	.0050	.0157	.0050	.000112	4,810,000
50000	673	.0280	.0057	.0169	.0062	.000140	4,810,000
55000	740	.0300	.0059	.0180	.0073	.000160	4,625,000
60000	807	.0314	.0062	.0188	.0081	.000180	4,480,000
65000	874	.0328	.0066	.0197	.0091	.000200	4,370,000
70000	942	.0342	.0071	.0207	.0100	.000220	4,280,000
75000	1022	.0360	.0073	.0216	.0109	.000245	4,180,000
80000	1077	.0374	.0078	.0226	.0119	.000269	4,000,000
85000	1144	.0389	.0083	.0236	.0129	.000290	3,950,000
90000	1210	.0408	.0086	.0247	.0140	.000314	3,860,000
95000	1280	.0420	.0093	.0257	.0150	.000338	3,790,000
100000	1344	.0441	.0096	.0269	.0162	.000364	3,690,000
105000	1411	.0458	.0105	.0282	.0175	.000393	3,590,000
110000	1480	.0473	.0107	.0290	.0183	.000411	3,600,000
115000	1545	.0493	.0110	.0302	.0195	.000438	3,530,000
120000	1615	.0514	.0117	.0316	.0209	.000470	3,440,000
125000	1680	.0531	.0124	.0328	.0221	.000496	3,390,000
130000	1750	.0550	.0130	.0340	.0233	.000523	3,350,000
135000	1815	.0574	.0139	.0357	.0250	.000562	3,230,000
140000	1881	.0597	.0149	.0373	.0264	.000593	3,170,000
145000	1950	.0618	.0160	.0389	.0282	.000634	3,080,000
150000	2015	.0634	.0166	.0400	.0293	.000659	3,060,000
155000	2085	.0651	.0171	.0411	.0304	.000684	3,050,000
160000	2150	.0674	.0184	.0429	.0322	.000723	2,970,000
165000	2220	.0695	.0197	.0446	.0339	.000761	2,910,000
170000	2285	.0719	.0217	.0468	.0361	.000810	2,820,000
175000	2350	.0735	.0232	.0484	.0377	.000847	2,770,000

COMPRESSIVE TEST OF COLUMN 2 (Contd.)

LOAD		COMPRESSOMETER READINGS			COMPRESSION		MODULUS OF ELASTICITY
Actual	Per Sq. Inch	L.	R.	Mean	Actual	Per Inch	E
180000	2420	.0762	.0245	.0504	.0397	.000892	2,710,000
185000	2490	.0788	.0261	.0524	.0417	.000935	2,660,000
190000	2555	.0818	.0274	.0546	.0439	.000987	2,590,000
195000	2620	.0845	.0288	.0566	.0459	.001030	2,540,000
200000	2690	.0885	.0300	.0593	.0486	.001090	2,460,000
205000	2760	.0933	.0312	.0623	.0516	.001160	2,380,000
210000	2825	.1008	.0318	.0663	.0556	.001250	2,260,000
215000	2890	.1071	.0324	.0698	.0591	.001330	2,170,000
220000	2960	.1157	.0327	.0742	.0635	.001430	2,070,000
225000	3030	.1256	.0330	.0793	.0686	.001540	1,970,000
230000	3095	.1387	.0329	.0858	.0751	.001685	1,835,000
235000	3160	.1556	.0315	.0936	.0829	.001860	1,700,000
240000	3230	.1792	.0276	.1034	.0921	.002065	1,570,000
245000	3300	.2010	.0250	.1130	.1023	.002300	1,430,000
250000	3360	.2406	.0092	.1249	.1142	.002575	1,305,000
255000	3430	.2827	-.0043	.1392	.1285	.002890	1,190,000
260000	3495	.3283	-.0213	.1535	.1428	.003210	1,090,000
265000	3560	.3779	-.0443	.1668	.1561	.003510	1,010,000
270000	3630	.4326	-.0714	.1806	.1699	.003820	950,000
275000	3700	.4936	-.1040	.1948	.1841	.004140	893,000
280000	3760	.5607	-.1283	.2162	.2055	.004620	814,000

Ultimate Strength = 3760 lbs. per sq. inch

LOG SHEET FOR SPIRAL DEFORMATIONS

Length Under Measurement = 6 circum. = 183 in.
Percentage Reinforcement = 2.76

Total Stress on Column	Stress on Unit area of Column	Total El. of Spiral Steel	El. of Spiral Steel per unit length	Stress per Sq. in. on Spiral St.
2100	28.3	0		
10000	134.7	0		
20000	269	0		
32000	431	0		
40000	538	0		
50000	673	.0025	.00001	
55000	740	.0025		
60000	807	.0025		
65000	874	.0025		
70000	942	.0025		
75000	1022	.0025		
80000	1077	.0025		
85000	1144	.0025		
90000	1210	.0025		
95000	1280	.0025		
100000	1344	.0025		
105000	1411	.0025		
110000	1480	.0025		
115000	1545	.0025		
120000	1615	.0025		
125000	1680	.0025		
130000	1750	.0025		
135000	1815	.0025		
140000	1881	.0025		
145000	1950	.0025		
150000	2015	.0025		
155000	2085	.0025		
160000	2150	.0025		
165000	2220	.0025		
170000	2285	.0025		
175000	2350	.0025		

SPIRAL DEFORMATIONS (Contd.)

Total Stress on Column	Stress on Unit Area of Column	Total El. of Spiral Steel	El. of Spiral Steel per Unit Length	Stress per Sq. in. on Spiral St.
180000	2420	.0025		
185000	2490	.0025		
190000	2555	.0025		
195000	2620	.0025	.00001	0
200000	2690	.0100	.00005	0
205000	2760	.0150	.00008	0
210000	2825	.0225	.00012	5000
215000	2890	.0300	.00016	6000
220000	2960	.0400	.00022	8000
225000	3030	.05475	.00030	9000
230000	3095	.06775	.00037	12200
235000	3160	.08250	.00045	15000
240000	3230	.1200	.00060	18800
245000	3300	.1425	.00078	24000
250000	3360	.1775	.00097	30000
255000	3430	.2250	.00123	36800
260000	3495	.2750	.00150	45200
265000	3560	.3225	.00176	52000
270000	3630	.3725	.00204	59000
275000	3700	.4200	.00229	64000
280000	3760	.4675	.00255	69300

APPENDIX

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CURVES

Chair Deformation.

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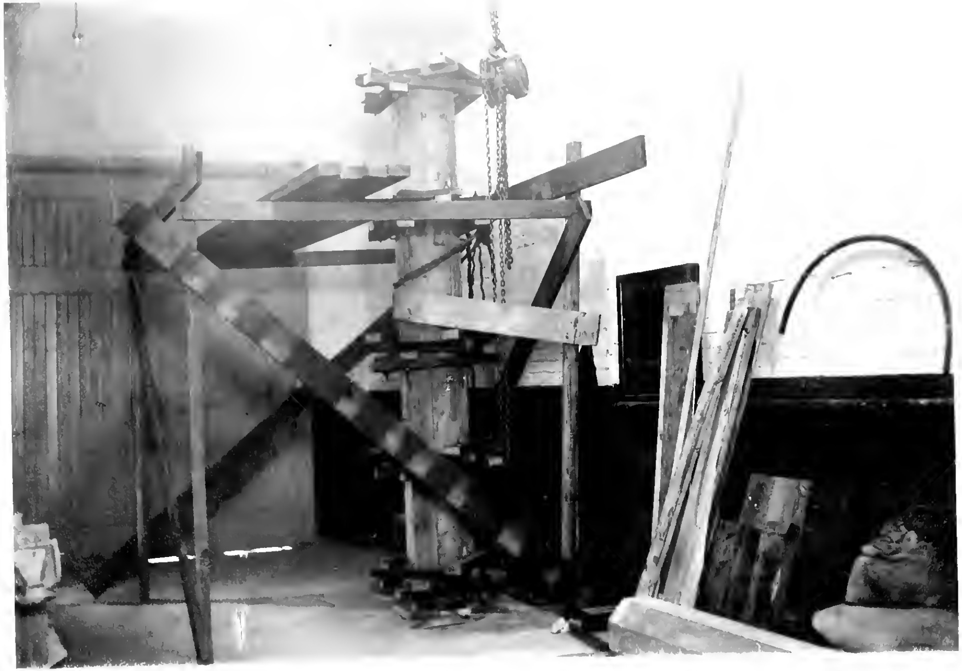

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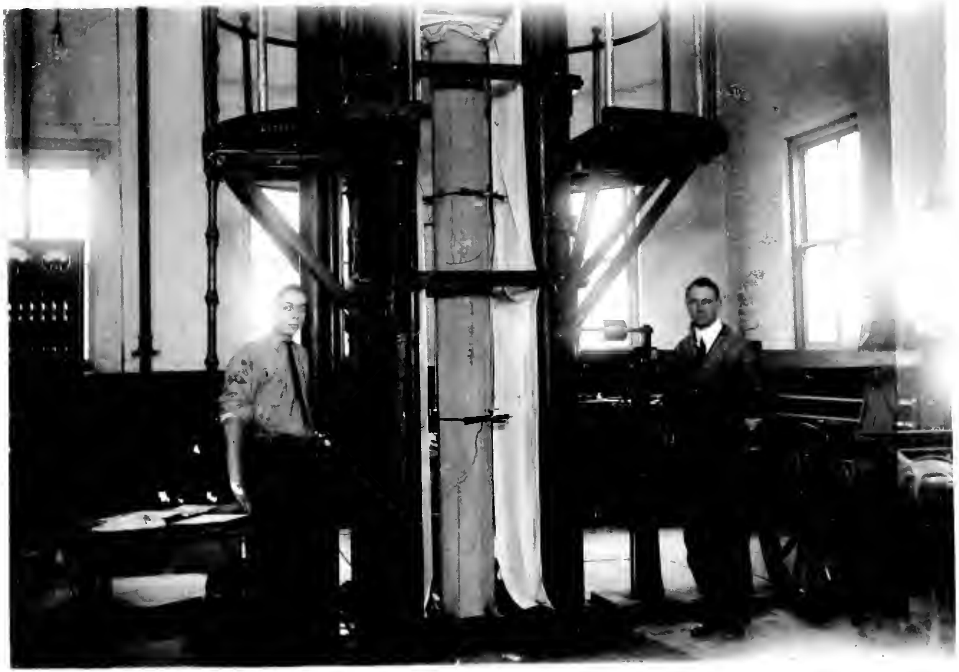
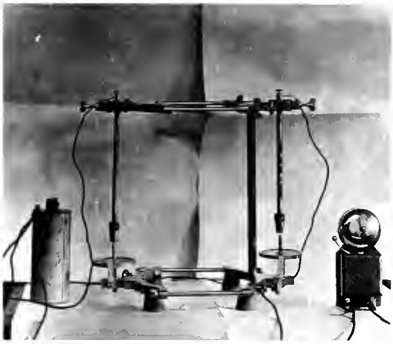


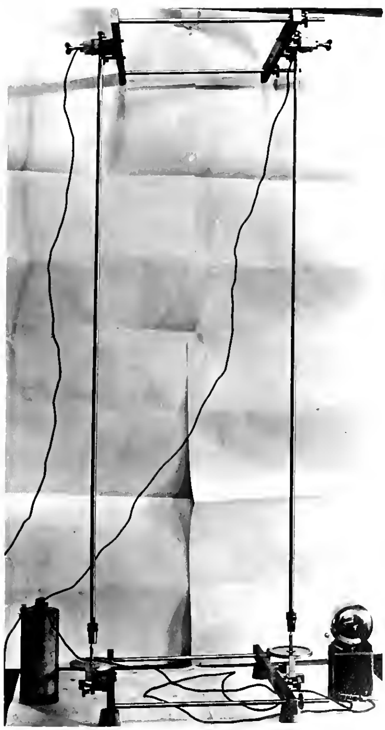
Column No. 1.

Column No. 1.

Column No. 2.



Extensometer
for
Cylinders.



Extensometer
for
Columns.